Characterizing Flow and Transport Processes at Yucca Mountain

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RESEARCH OBJECTIVES

Quantitative characterization of fluid flow and radionuclide transport in the unsaturated zone (UZ) at Yucca Mountain, Nevada, using a numerical model is an essential step for designing the potential repository and assessing its performance. Numerical modeling has played a crucial role in understanding UZ fluid movement and the effects of hydrogeologic, thermal and geochemical conditions on various aspects of the overall waste-disposal system. Whereas laboratory and field experiments are limited in both space and time, numerical modeling provides a means to study physical processes on large temporal and spatial scales relevant to understanding physical processes associated with nuclear waste disposal in a geologic formation. Modeling investigations summarized here were performed for evaluating the current and future conditions of the UZ so as to aid in the assessment of the potentail repository's system performance and to estimate groundwater travel and radionuclide transport times

APPROACH

The methodology used in developing the characterization studies includes (1) design of a 3-D numerical grid that properly represents complicated geological features of Yucca Mountain; (2) model calibrations against field data; and (3) flow and transport simulation studies using different infiltration rates and hydrogeological conceptual models. The modeling approach in the UZ flow and transport model is based on a continuum mathematical formulation of coupled multiphase fluid and tracer transport through fractured porous rock with the TOUGH2 code. The flow and transport processes in the fractured porous rock are handled using a dual-continuum concept.

ACCOMPLISHMENTS

A series of model calibrations and sensitivity analyses were conducted with the UZ flow and transport model to investigate the effects of variations in rock properties and in model boundary conditions, using different perched water conceptual models and different climate conditions. These model-calibration efforts conclude that the model can reproduce moisture conditions in the UZ system of Yucca Mountain. The model has been used to (1) integrate the available data from the UZ system into a single, comprehensive and calibrated 3-D model for simulating the ambient hydrological, thermal and geochemical conditions for use in predicting system response to future climate conditions; (2) quantify the moisture flow through the UZ, under present-day and estimated future climate scenarios; and (3) calculate times of radionuclide transport from the repository level to the water table.

Model results indicate that repository-level percolation fluxes largely reflect surface infiltration patterns. These percolation fluxes and their distributions show little large-scale lateral flow or diversion by the PTn unit and flow focusing into faults in the vicinity of the potential repository. Fracture flow is predicted to be dominant in the welded tuffs. Significant lateral flow diversion is predicted to occur at the CHn, resulting from the presence of perched water or thick low-permeability zeolitic layers. Faults act as major flow paths through the CHn unit and the percentage of fault flow versus total percolation fluxes increases as mean infiltration rates increase. Tracer-transport studies indicate that there exists a wide range of radionuclide transport times using different infiltration rates, types of radionuclides and perched water conceptual models. Infiltration rates and adsorption effects in the CHn unit were found to be the most important factors for estimated transport times.

Whereas laboratory and field experiments are limited in both space and time, numerical modeling provides a means to study physical processes on large temporal and spatial scales relevant to understanding physical processes associated with nuclear waste disposal in a geologic formation.

SIGNIFICANCE OF FINDINGS

The site-characterization efforts produced more than 30, 3-D steady-state flow fields, 18 of which have been directly used in the TSPA-SR analyses. In addition, the model results provide input to various other models, such as ambient and thermal drift-scale models, the mountain-scale thermohydrological model and the UZ transport model used for LA.

RELATED PUBLICATIONS

Wu, Y.S., C. Haukwa and G.S. Bodvarsson, A site-scale model for fluid and heat flow in the unsaturated zone of Yucca Mountain, Nevada, Journal of Contaminant Hydrology, 38 (1-3), pp.185-217, 1999.

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